UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
JANUARY 2017 SEMESTER

COURSE	**: VDB3032 / VCB3022 – DESIGN OF STEEL STRUCTURES**
DATE	**: 28 APRIL 2017 (FRIDAY)**
TIME	**: 9.00 AM – 12.00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions.
5. Do not open this Question Booklet until instructed.

Note : There are **NINETEEN (19)** pages in this Question Booklet including the cover page and **APPENDICES**.

1. a. **FIGURE Q1** shows a part of a floor plan. The steel beams, *B1*, *B2* and *B3* are supporting a 200 mm thick reinforced concrete floor slab. The floor is designed for a live load of 5 kN/m^2.

Given: Dead load factor of safety =1.35, Live load factor of safety = 1.5 and density of concrete = 2400 kg/m^3.

i. Draw sketches showing how the load on the floor will be distributed to the beams.

[5 marks]

ii. By assuming beam *B2* is simply supported at both ends, determine the design reactions that will be transferred to the columns C and D.

[10 marks]

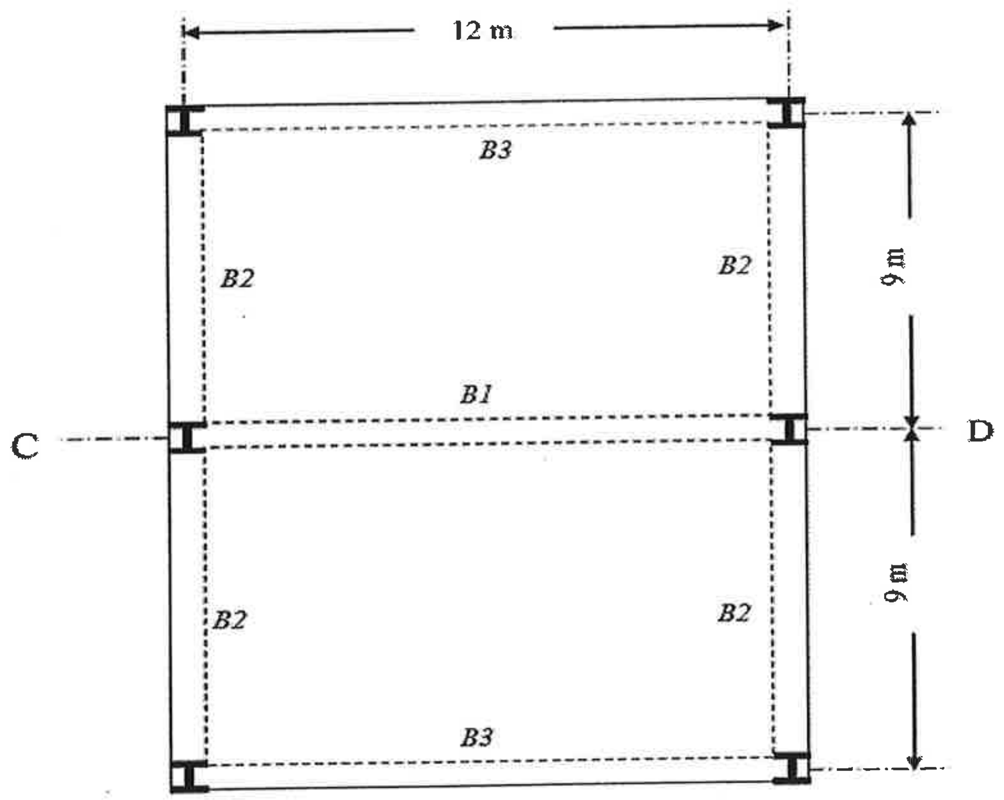

FIGURE Q1

1. b. A UC 305 × 305 × 240 with grade S460 steel (Fy = 440 N/mm^2) is to be used as internal column with 4.0 m height. The column is pinned at one end and fully welded at the other end (l_{cr}=0.85L). Modulus of elasticity for the steel is 200 kN/mm^2.

i. Determine the type of the column. [3 Marks]

ii. Evaluate the design buckling resistance ($N_{b,Rd}$) of the column. [12 Marks]

2. a. **FIGURE Q2a** shows a 15 mm thick steel tension plate containing three lines of staggered holes drilled for 20 mm diameter bolts. The plate is made of steel grade S355. Determine the safe design load, *P* that can be transferred by the plate.

[10 marks]

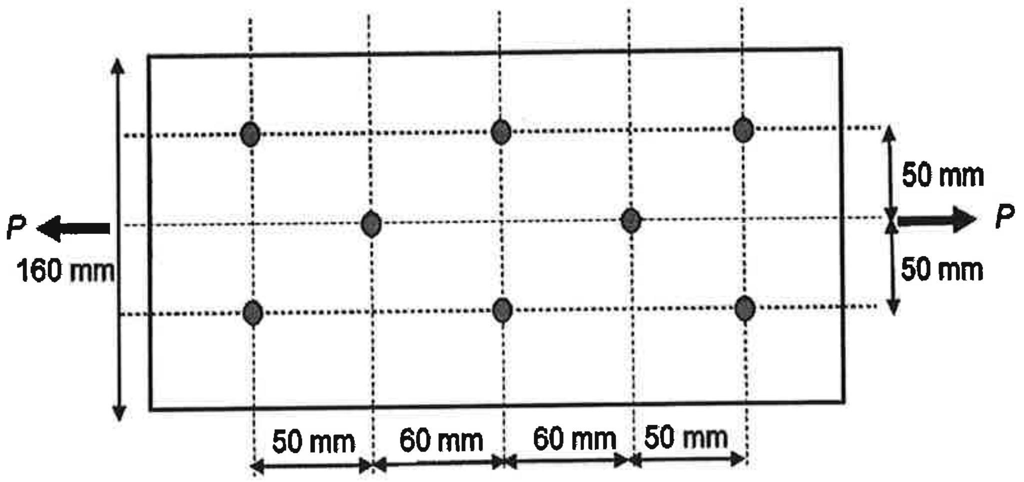

FIGURE Q2a

b. **FIGURE Q2b** shows a 8 m simply supported beam subjected to a central point load (PL) made up of 55 kN dead load and 110 kN imposed load. Assuming that the beam is fully restrained (no buckling of compression flange). Modulus of elasticity for the steel is 200 kN/mm².

i. Select a suitable universal beam section of a grade S275 steel based on the least weight.

[5 marks]

ii. Verify the suitability of the selected section against applied bending moment and shear force.

[10 marks]

iii. Evaluate the deflection of the beam under total load.

[5 marks]

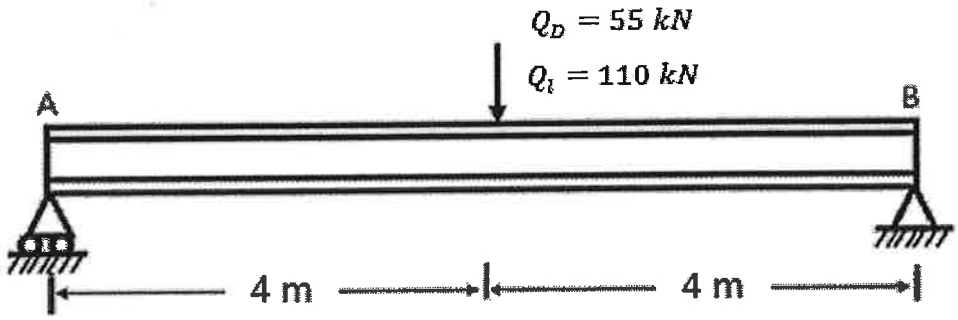

FIGURE Q2b

3. **FIGURE Q3** shows a lap joint subjected to 50 kN eccentric load. Two 12 mm thick S275 plates have been joined using a single bolt of 18 mm diameter and grade 8.8. Check this lap joint with respect to the following: (Given: Tensile area, A_t=245 mm^2).

a. Minimum and maximum edge and end distances

[5 marks]

b. Load capacity of the connection with respect to Bolt shear, Bolt bearing, Plate bearing and Block shear

[10 marks]

c. Tension capacity of plates

[5 marks]

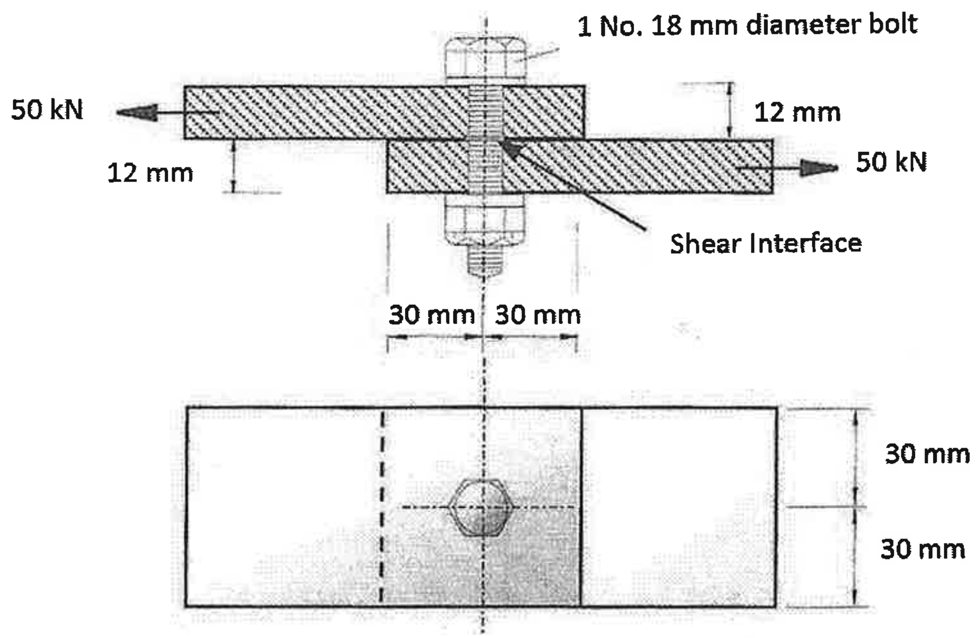

FIGURE Q3

4. a. **FIGURE Q4** shows a single bay portal frame. The frame has a uniform full plastic moment capacity of 20 kN.m. The unfactored loads acting on the frame are shown in the figure.

Identify the possible locations for plastic hinges and number of mechanisms.

[5 marks]

b. Evaluate the load factors for different possible mechanisms.

[10 marks]

c. Determine the correct collapse mechanism and the load factor against collapse.

[5 marks]

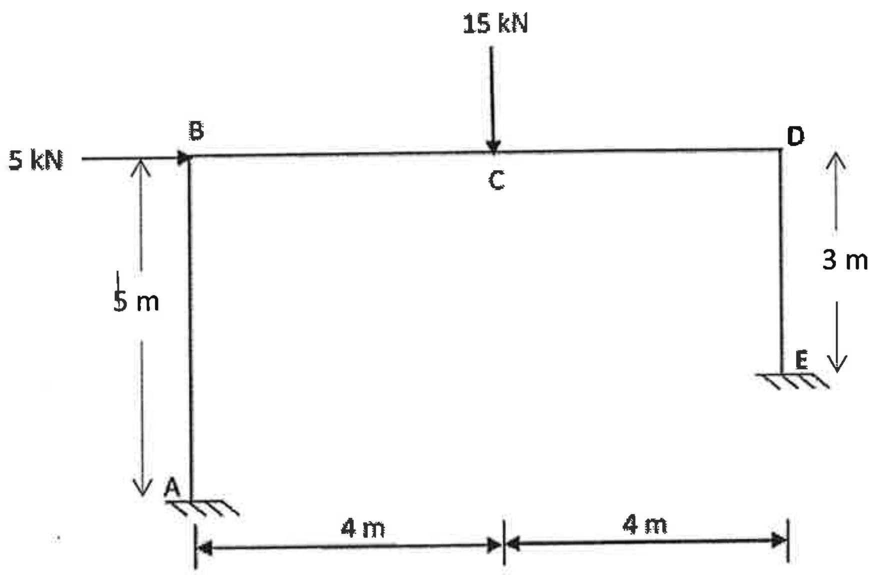

FIGURE Q3

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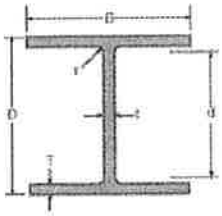
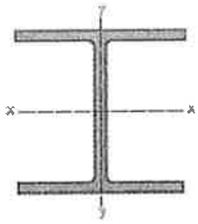
Universal column Section Properties and Dimensions



Designation: Serial size		Mass per metre kg/m	Depth of section D mm	Width of section B mm	Thickness of web t mm	Thickness of flange T mm	Root radius r mm	Depth between fillets d mm	Ratios for local buckling: Flange B/2T	Ratios for local buckling: Web d/t	Second moment of area: Axis x-x cm⁴	Second moment of area: Axis y-y cm⁴	Radius of gyration: Axis x-x cm	Radius of gyration: Axis y-y cm
356x406	634	633.9	474.6	424.0	47.6	77.0	15.2	290.2	2.75	6.10	274845	98125	18.4	11.0
	551	551.0	455.6	418.5	42.1	67.5	15.2	290.2	3.10	6.89	226938	82671	18.0	10.9
	467	467.0	436.6	412.2	35.8	58.0	15.2	290.2	3.55	8.11	183003	67834	17.5	10.7
	393	393.0	419.0	407.0	30.6	49.2	15.2	290.2	4.14	9.48	146618	55367	17.1	10.5
	340	339.9	406.4	403.0	26.6	42.9	15.2	290.2	4.70	10.9	122543	46853	16.8	10.4
	287	287.1	393.6	399.0	22.6	36.5	15.2	290.2	5.47	12.8	99875	38677	16.5	10.3
	235	235.1	381.0	394.8	18.4	30.2	15.2	290.2	6.54	15.8	79085	30993	16.3	10.2
356x368	202	201.9	374.6	374.7	16.5	27.0	15.2	290.2	6.94	17.6	66261	23688	16.1	9.60
	177	177.0	368.2	372.6	14.4	23.8	15.2	290.2	7.83	20.2	57118	20529	15.9	9.54
	153	152.9	362.0	370.5	12.3	20.7	15.2	290.2	8.95	23.6	48589	17553	15.8	9.49
	129	129.0	355.6	368.6	10.4	17.5	15.2	290.2	10.5	27.9	40246	14611	15.6	9.43
305x305	283	282.9	365.3	322.2	26.8	44.1	15.2	246.7	3.65	9.21	78872	24635	14.8	8.27
	240	240.0	352.5	318.4	23.0	37.7	15.2	246.7	4.22	10.7	64203	20315	14.5	8.15
	198	198.1	339.9	314.5	19.1	31.4	15.2	246.7	5.01	12.9	50904	16299	14.2	8.04
	158	158.1	327.1	311.2	15.8	25.0	15.2	246.7	6.22	15.6	38747	12569	13.9	7.90
	137	136.9	320.5	309.2	13.8	21.7	15.2	246.7	7.12	17.9	32814	10700	13.7	7.83
	118	117.9	314.5	307.4	12.0	18.7	15.2	246.7	8.22	20.6	27672	9059	13.6	7.77
	97	96.9	307.9	305.3	9.9	15.4	15.2	246.7	9.91	24.9	22249	7308	13.4	7.69
254x254	167	167.1	289.1	265.2	19.2	31.7	12.7	200.3	4.18	10.4	29998	9870	11.9	6.81
	132	132.0	276.3	261.3	15.3	25.3	12.7	200.3	5.16	13.1	22529	7531	11.6	6.69
	107	107.1	266.7	258.8	12.8	20.5	12.7	200.3	6.31	15.6	17510	5928	11.3	6.59
	89	88.9	260.3	256.3	10.3	17.3	12.7	200.3	7.41	19.4	14268	4857	11.2	6.55
	73	73.1	254.1	254.6	8.6	14.2	12.7	200.3	8.96	23.3	11407	3908	11.1	6.48
203x203	127	127.5	241.4	213.9	18.1	30.1	10.2	160.8	3.55	8.88	15437	4920	9.75	5.50
	113	113.5	235.0	212.1	16.3	26.9	10.2	160.8	3.94	9.87	13301	4285	9.59	5.45
	100	99.6	228.6	210.3	14.5	23.7	10.2	160.8	4.44	11.1	11298	3679	9.44	5.39
	86	86.1	222.2	209.1	12.7	20.5	10.2	160.8	5.10	12.7	9449	3127	9.28	5.34
	71	71.0	215.8	206.4	10.0	17.3	10.2	160.8	5.97	16.1	7618	2537	9.18	5.30
	60	60.0	209.6	205.8	9.4	14.2	10.2	160.8	7.25	17.1	6125	2065	8.96	5.20
	52	52.0	206.2	204.3	7.9	12.5	10.2	160.8	8.17	20.4	5259	1778	8.91	5.18
	46	46.1	203.2	203.6	7.2	11.0	10.2	160.8	9.25	22.3	4568	1548	8.82	5.13
152x152	51	51.2	170.2	157.4	11.0	15.7	7.6	123.6	5.01	11.2	3227	1022	7.04	3.96
	44	44.0	166.0	155.9	9.5	13.6	7.6	123.6	5.73	13.0	2703	860	6.94	3.92
	37	37.0	161.8	154.4	8.0	11.5	7.6	123.6	6.71	15.5	2210	706	6.85	3.87
	30	30.0	157.6	152.9	6.5	9.4	7.6	123.6	8.13	19.0	1748	560	6.76	3.83
	23	23.0	152.4	152.2	5.8	6.8	7.6	123.6	11.2	21.3	1250	400	6.54	3.70

Universal column Section Properties and Dimensions



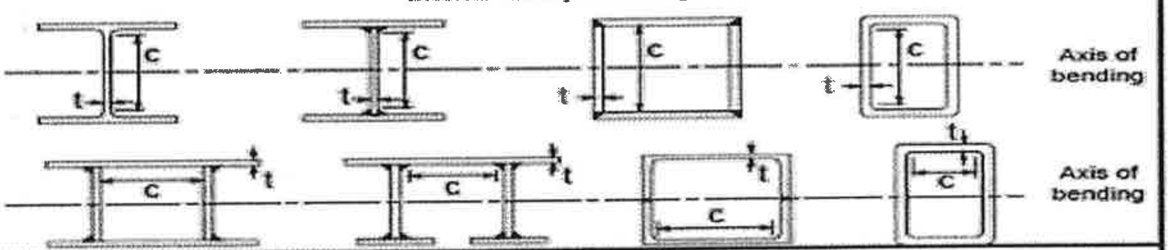
Elastic modulus Axis x-x cm^3	Elastic modulus Axis y-y cm^3	Plastic modulus Axis x-x cm^3	Plastic modulus Axis y-y cm^3	Buckling parameter u	Torsional index x	Warping constant H dm^6	Torsional constant J cm^4	Area of section cm^2	Indicative values for Advance275 Mcx* kNm	Indicative values for Advance275 Pcy for L_E=3.5m kN	Designation	Serial size
11582	4629	14235	7108	0.843	5.46	38.8	13720	808	*3410*	17600	634	356x406
9962	3951	12076	6058	0.841	6.05	31.1	9240	702	*2930*	15300	551	
8383	3291	10003	5034	0.839	6.86	24.3	5809	595	2550	13400	467	
6998	2721	8223	4154	0.837	7.86	18.9	3545	501	2100	11400	393	
6031	2325	6999	3544	0.836	8.85	15.5	2343	433	1780	9840	340	
5075	1939	5813	2949	0.835	10.2	12.3	1441	366	1540	8780	287	
4151	1570	4687	2383	0.834	12.1	9.54	812	299	1240	7150	235	
3538	1264	3972	1919	0.844	13.4	7.16	558	257	1050	6060	202	356x368
3103	1102	3455	1671	0.844	15.0	6.09	381	226	916	5320	177	
2684	948	2965	1435	0.844	17.0	5.11	251	195	786	4590	153	
2264	793	2479	1199	0.844	19.9	4.18	153	164	651	3850	129	
4318	1529	5105	2342	0.855	7.65	6.35	2034	360	1300	7640	283	305x305
3643	1276	4247	1950	0.854	8.74	5.03	1271	306	1130	6890	240	
2995	1037	3440	1581	0.854	10.2	3.88	734	252	912	5650	198	
2369	808	2681	1230	0.851	12.5	2.87	378	201	710	4480	158	
2048	692	2297	1052	0.851	14.2	2.39	249	174	609	3870	137	
1760	589	1958	895	0.850	16.2	1.98	161	150	519	3330	118	
1445	479	1592	726	0.850	19.3	1.56	91.2	123	438	2810	97	
2075	744	2424	1137	0.851	8.49	1.63	626	213	642	4490	167	254x254
1631	576	1869	878	0.850	10.3	1.19	319	168	495	3510	132	
1313	458	1485	697	0.848	12.4	0.898	172	136	393	2820	107	
1096	379	1224	575	0.850	14.5	0.717	102	113	324	2340	89	
898	307	992	465	0.849	17.3	0.562	57.6	93.1	273	1980	73	
1279	460	1517	704	0.854	7.38	0.549	427	162	402	3050	127	203x203
1132	404	1329	618	0.853	8.11	0.464	305	145	352	2710	113	
988	350	1148	534	0.852	9.02	0.386	210	127	304	2360	100	
850	299	977	456	0.850	10.2	0.318	137	110	259	2030	86	
706	246	799	374	0.853	11.9	0.250	80.2	90.4	212	1660	71	
584	201	656	305	0.846	14.1	0.197	47.2	76.4	180	1430	60	
510	174	567	264	0.848	15.8	0.167	31.8	66.3	156	1230	52	
450	152	497	231	0.847	17.7	0.143	22.2	58.7	137	1080	46	
379	130	438	199	0.848	10.1	0.0610	48.8	65.2	120	947	51	152x152
326	110	372	169	0.848	11.5	0.0499	31.7	56.1	102	806	44	
273	91	309	140	0.848	13.3	0.0399	19.2	47.1	84.9	667	37	
222	73	248	112	0.849	16.0	0.0308	10.5	38.3	68.1	536	30	
164	53	182	80	0.840	20.7	0.0212	4.63	29.2	48.4	392	23	

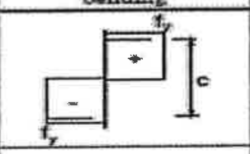
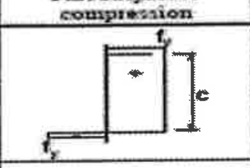
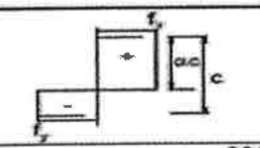
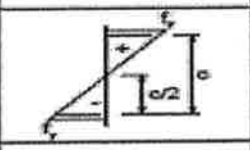
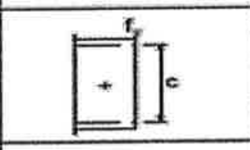
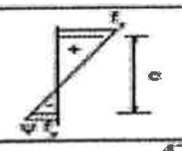
Nominal Values of Yield Strength f_y and Ultimate Tensile Strength f_u for Hot Rolled Structural Steel

Standard and steel grade	Nominal thickness of the element t [mm]			
	$t \leq 40$ mm		$40 \text{ mm} < t \leq 80$ mm	
	f_y [N/mm^2]	f_u [N/mm^2]	f_y [N/mm^2]	f_u [N/mm^2]
EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	510	335	470
S 450	440	550	410	550

Table 5.2 (sheet 1 of 3): Maximum width-to-thickness ratios for compression parts

Internal compression parts



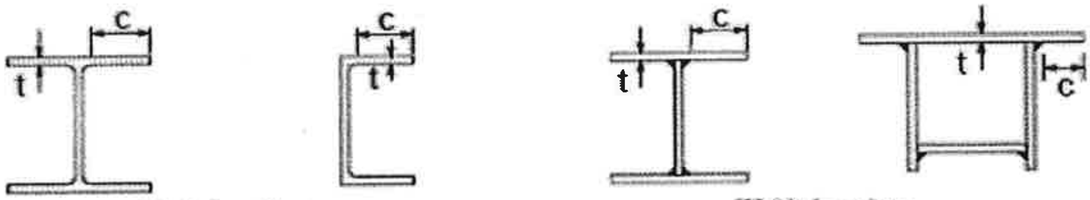
Class	Part subject to bending	Part subject to compression	Part subject to bending and compression
Stress distribution in parts (compression positive)			
1	$c/t \leq 72\varepsilon$	$c/t \leq 33\varepsilon$	when $\alpha > 0{,}5$: $c/t \leq \frac{396\varepsilon}{13\alpha - 1}$ when $\alpha \leq 0{,}5$: $c/t \leq \frac{36\varepsilon}{\alpha}$
2	$c/t \leq 83\varepsilon$	$c/t \leq 38\varepsilon$	when $\alpha > 0{,}5$: $c/t \leq \frac{456\varepsilon}{13\alpha - 1}$ when $\alpha \leq 0{,}5$: $c/t \leq \frac{41{,}5\varepsilon}{\alpha}$
Stress distribution in parts (compression positive)			
3	$c/t \leq 124\varepsilon$	$c/t \leq 42\varepsilon$	when $\psi > -1$: $c/t \leq \frac{42\varepsilon}{0{,}67 + 0{,}33\psi}$ when $\psi \leq -1$*): $c/t \leq 62\varepsilon(1-\psi)\sqrt{(-\psi)}$

$\varepsilon = \sqrt{235/f_y}$	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

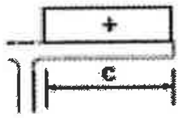
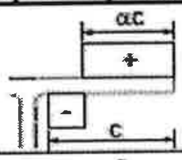
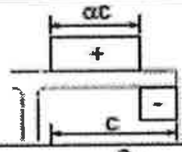
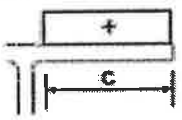
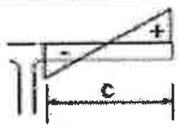
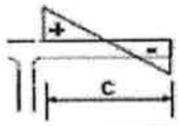
*) $\psi \leq -1$ applies where either the compression stress $\sigma \leq f_y$ or the tensile strain $\varepsilon_y > f_y/E$

Table 5.2 (sheet 2 of 3): Maximum width-to-thickness ratios for compression parts

Outstand flanges



Rolled sections — Welded sections

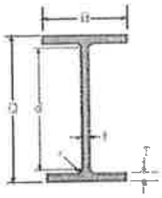
Class	Part subject to compression	Part subject to bending and compression: Tip in compression	Part subject to bending and compression: Tip in tension
Stress distribution in parts (compression positive)			
1	$c/t \le 9\varepsilon$	$c/t \le \frac{9\varepsilon}{\alpha}$	$c/t \le \frac{9\varepsilon}{\alpha\sqrt{\alpha}}$
2	$c/t \le 10\varepsilon$	$c/t \le \frac{10\varepsilon}{\alpha}$	$c/t \le \frac{10\varepsilon}{\alpha\sqrt{\alpha}}$
Stress distribution in parts (compression positive)			
3	$c/t \le 14\varepsilon$	$c/t \le 21\varepsilon\sqrt{k_\sigma}$ For k_σ see EN 1993-1-5	

$\varepsilon = \sqrt{235/f_y}$	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

Table 4.1: Correlation factor β_w for fillet welds

Standard and steel grade			Correlation factor β_w
EN 10025	**EN 10210**	**EN 10219**	
S 235 S 235 W	S 235 H	S 235 H	0,8
S 275 S 275 N/NL S 275 M/ML	S 275 H S 275 NH/NLH	S 275 H S 275 NH/NLH S 275 MH/MLH	0,85
S 355 S 355 N/NL S 355 M/ML S 355 W	S 355 H S 355 NH/NLH	S 355 H S 355 NH/NLH S 355 MH/MLH	0,9
S 420 N/NL S 420 M/ML		S 420 MH/MLH	1,0
S 460 N/NL S 460 M/ML S 460 Q/QL/QL1	S 460 NH/NLH	S 460 NH/NLH S 460 MH/MLH	1,0

Universal Beam Sections Properties and Dimensions



Designation Serial size		Mass per metre kg/m	Depth of section D mm	Width of section B mm	Thickness of web t mm	Thickness of flange T mm	Root radius r mm	Depth between fillets d mm	Ratios for local buckling Flange B/2T	Web d/t	Second moment of area Axis x-x cm^4	Axis y-y cm^4	Radius of gyration Axis x-x cm	Axis y-y cm
457x191	161	161.4	492.0	199.4	18.0	32.0	10.2	407.6	3.12	22.6	79779	4250	19.7	4.55
	133	133.3	480.6	196.7	15.3	26.3	10.2	407.6	3.74	26.6	63841	3350	19.4	4.44
	106	105.8	469.2	194.0	12.6	20.6	10.2	407.6	4.71	32.3	48873	2515	19.0	4.32
	98	98.3	467.2	192.8	11.4	19.6	10.2	407.6	4.92	35.8	45727	2347	19.1	4.33
	89	89.3	463.4	191.9	10.5	17.7	10.2	407.6	5.42	38.8	41015	2089	19.0	4.29
	82	82.0	460.0	191.3	9.9	16.0	10.2	407.6	5.98	41.2	37051	1871	18.8	4.23
	74	74.3	457.0	190.4	9.0	14.5	10.2	407.6	6.57	45.3	33319	1671	18.8	4.20
	67	67.1	453.4	189.9	8.5	12.7	10.2	407.6	7.48	48.0	29380	1452	18.5	4.12
457x152	82	82.1	465.8	155.3	10.5	18.9	10.2	407.6	4.11	38.8	36589	1185	18.7	3.37
	74	74.2	462.0	154.4	9.6	17.0	10.2	407.6	4.54	42.5	32674	1047	18.6	3.33
	67	67.2	458.0	153.8	9.0	15.0	10.2	407.6	5.13	45.3	28927	913	18.4	3.27
	60	59.8	454.6	152.9	8.1	13.3	10.2	407.6	5.75	50.3	25500	795	18.3	3.23
	52	52.3	449.8	152.4	7.6	10.9	10.2	407.6	6.99	53.6	21369	645	17.9	3.11
406x178	85	85.3	417.2	181.9	10.9	18.2	10.2	360.4	5.00	33.1	31703	1830	17.1	4.11
	74	74.2	412.8	179.5	9.5	16.0	10.2	360.4	5.61	37.9	27310	1545	17.0	4.04
	67	67.1	409.4	178.8	8.8	14.3	10.2	360.4	6.25	41.0	24331	1365	16.9	3.99
	60	60.1	406.4	177.9	7.9	12.8	10.2	360.4	6.95	45.6	21596	1203	16.8	3.97
	54	54.1	402.6	177.7	7.7	10.9	10.2	360.4	8.15	46.8	18722	1021	16.5	3.85
406x140	53	53.3	406.6	143.3	7.9	12.9	10.2	360.4	5.55	45.6	18283	635	16.4	3.06
	46	46.0	403.2	142.2	6.8	11.2	10.2	360.4	6.35	53.0	15685	538	16.4	3.03
	39	39.0	398.0	141.8	6.4	8.6	10.2	360.4	8.24	56.3	12508	410	15.9	2.87
356x171	67	67.1	363.4	173.2	9.1	15.7	10.2	311.6	5.52	34.2	19463	1362	15.1	3.99
	57	57.0	358.0	172.2	8.1	13.0	10.2	311.6	6.62	38.5	16038	1108	14.9	3.91
	51	51.0	355.0	171.5	7.4	11.5	10.2	311.6	7.46	42.1	14136	968	14.8	3.86
	45	45.0	351.4	171.1	7.0	9.7	10.2	311.6	8.82	44.5	12066	811	14.5	3.76
356x127	39	39.1	353.4	126.0	6.6	10.7	10.2	311.6	5.89	47.2	10172	358	14.3	2.68
	33	33.1	349.0	125.4	6.0	8.5	10.2	311.6	7.38	51.9	8249	280	14.0	2.58
305x165	54	54.0	310.4	166.9	7.9	13.7	8.9	265.2	6.09	33.6	11696	1063	13.0	3.93
	46	46.1	306.6	165.7	6.7	11.8	8.9	265.2	7.02	39.6	9899	896	13.0	3.90
	40	40.3	303.4	165.0	6.0	10.2	8.9	265.2	8.09	44.2	8503	764	12.9	3.86
305x127	48	48.1	311.0	125.3	9.0	14.0	8.9	265.2	4.48	29.5	9575	461	12.5	2.74
	42	41.9	307.2	124.3	8.0	12.1	8.9	265.2	5.14	33.2	8196	389	12.4	2.70
	37	37.0	304.4	123.4	7.1	10.7	8.9	265.2	5.77	37.4	7171	336	12.3	2.67
305x102	33	32.8	312.7	102.4	6.6	10.8	7.6	275.9	4.74	41.8	6501	194	12.5	2.15
	28	28.2	308.7	101.8	6.0	8.8	7.6	275.9	5.78	46.0	5366	155	12.2	2.08
	25	24.8	305.1	101.6	5.8	7.0	7.6	275.9	7.26	47.6	4455	123	11.9	1.97
254x146	43	43.0	259.6	147.3	7.2	12.7	7.6	219.0	5.80	30.4	6544	677	10.9	3.52
	37	37.0	256.0	146.4	6.3	10.9	7.6	219.0	6.72	34.8	5537	571	10.8	3.48
	31	31.1	251.4	146.1	6.0	8.6	7.6	219.0	8.49	36.5	4413	448	10.5	3.36
254x102	28	28.3	260.4	102.2	6.3	10.0	7.6	225.2	5.11	35.7	4005	179	10.5	2.22
	25	25.2	257.2	101.9	6.0	8.4	7.6	225.2	6.07	37.5	3415	149	10.3	2.15
	22	22.0	254.0	101.6	5.7	6.8	7.6	225.2	7.47	39.5	2841	119	10.1	2.06
203x133	30	30.0	206.8	133.9	6.4	9.6	7.6	172.4	6.97	26.9	2896	385	8.71	3.17
	25	25.1	203.2	133.2	5.7	7.8	7.6	172.4	8.54	30.2	2340	308	8.56	3.10
203x102	23	23.1	203.2	101.8	5.4	9.3	7.6	169.4	5.47	31.4	2105	164	8.46	2.36
178x102	19	19.0	177.8	101.2	4.8	7.9	7.6	146.8	6.41	30.6	1356	137	7.48	2.37
152x89	16	16.0	152.4	88.7	4.5	7.7	7.6	121.8	5.76	27.1	834	90	6.41	2.10
127x76	13	13.0	127.0	76.0	4.0	7.6	7.6	96.6	5.00	24.2	473	56	5.35	1.84

APPENDIX

Universal Beam Sections Properties and Dimensions

Elastic modulus Axis x-x cm^3	Elastic modulus Axis y-y cm^3	Plastic modulus Axis x-x cm^3	Plastic modulus Axis y-y cm^3	Buckling parameter u	Torsional index x	Warping constant H dm^6	Torsional constant J cm^4	Area of section cm^2	Indicative values for Advance275 Mcx kNm	Pcy for L_E=3.5m kN	Designation	Serial size
3243	426	3778	672	0.882	16.4	2.25	515	206	1000	3770	161	457x191
2657	341	3070	535	0.880	19.6	1.73	292	170	814	3050	133	
2083	259	2389	405	0.877	24.4	1.27	146	135	633	2360	106	
1957	243	2232	379	0.881	25.7	1.18	121	125	592	2190	98	
1770	218	2014	338	0.880	28.3	1.04	90.7	114	534	1980	89	
1611	196	1831	304	0.877	30.9	0.922	69.2	104	504	1830	82	
1458	176	1653	272	0.877	33.9	0.818	51.8	94.6	455	1650	74	
1296	153	1471	237	0.872	37.9	0.705	37.1	85.5	405	1460	67	
1571	153	1812	240	0.873	27.4	0.591	89.2	105	480	1380	82	457x152
1414	136	1627	213	0.873	30.1	0.518	65.9	94.5	431	1220	74	
1263	119	1453	187	0.869	33.6	0.448	47.7	85.6	400	1100	67	
1122	104	1287	163	0.868	37.5	0.387	33.8	76.2	354	959	60	
950	85	1096	133	0.859	43.9	0.311	21.4	66.6	301	793	52	
1520	201	1733	313	0.881	24.4	0.728	93.0	109	459	1820	85	406x178
1323	172	1501	267	0.882	27.6	0.608	62.8	94.5	413	1580	74	
1189	153	1346	237	0.880	30.5	0.533	46.1	85.5	370	1410	67	
1063	135	1200	209	0.880	33.8	0.466	33.3	76.5	330	1260	60	
930	115	1055	178	0.871	38.3	0.392	23.1	69.0	290	1090	54	
899	89	1031	139	0.870	34.1	0.246	29.0	67.9	284	789	53	406x140
778	76	888	118	0.871	38.9	0.207	19.0	58.6	244	671	46	
629	58	724	91	0.858	47.5	0.155	10.7	49.7	199	523	39	
1071	157	1211	243	0.886	24.4	0.412	55.7	85.6	333	1410	67	356x171
896	129	1010	199	0.882	28.8	0.330	33.4	72.6	278	1170	57	
796	113	896	174	0.881	32.1	0.286	23.8	64.9	246	1030	51	
687	95	775	147	0.874	36.8	0.237	15.8	57.3	213	884	45	
576	57	659	89	0.871	35.2	0.105	15.1	49.8	181	469	39	356x127
473	45	543	70	0.863	42.2	0.0812	8.79	42.1	149	372	33	
754	127	846	196	0.889	23.6	0.234	34.8	68.8	233	1120	54	305x165
646	108	720	166	0.891	27.1	0.195	22.2	58.7	198	945	46	
560	93	623	142	0.889	31.0	0.164	14.7	51.3	171	816	40	
616	74	711	116	0.873	23.3	0.102	31.8	61.2	195	597	48	305x127
534	63	614	98	0.872	26.5	0.0846	21.1	53.4	169	509	42	
471	54	539	85	0.872	29.7	0.0725	14.8	47.2	148	442	37	
416	38	481	60	0.866	31.6	0.0442	12.2	41.8	132	269	33	305x102
348	31	403	48	0.859	37.4	0.0349	7.40	35.9	111	218	28	
292	24	342	39	0.846	43.4	0.0273	4.77	31.6	94.1	174	25	
504	92	566	141	0.891	21.2	0.103	23.9	54.8	156	777	43	254x146
433	78	483	119	0.890	24.3	0.0857	15.3	47.2	133	659	37	
351	61	393	94	0.880	29.6	0.0660	8.55	39.7	108	529	31	
308	35	353	55	0.874	27.5	0.0280	9.57	36.1	97.0	246	28	254x102
266	29	306	46	0.866	31.5	0.0230	6.42	32.0	84.0	206	25	
224	23	259	37	0.856	36.4	0.0182	4.15	28.0	71.2	167	22	
280	57	314	88	0.881	21.5	0.0374	10.3	38.2	86.5	468	30	203x133
230	46	258	71	0.877	25.6	0.0294	5.96	32.0	70.9	379	25	
207	32	234	50	0.888	22.5	0.0154	7.02	29.4	64.4	223	23	203x102
153	27	171	42	0.888	22.6	0.0099	4.41	24.3	47.1	186	19	178x102
109	20	123	31	0.890	19.6	0.0047	3.56	20.3	33.9	125	16	152x89
75	15	84	23	0.895	16.3	0.0020	2.85	16.5	23.1	80.3	13	127x76

Various Information

- Partial safety factors:

  $\gamma_{M0} = 1$

  $\gamma_{M2} = 1.25$

- Area deduction for inclined failure path:

$$ntd - \sum \frac{s^2 t}{4g}$$

- Design plastic resistance of the gross cross section:

$$N_{pl,Rd} = \frac{A f_y}{\gamma_{M0}}$$

- Design ultimate resistance of the net cross section at holes for fasteners

$$N_{u,Rd} = \frac{0.9 A_{net} f_u}{\gamma_{M2}}$$

- $V_{pl.Rd} = Av\,(fy/\sqrt{3})/\ \gamma_{M0}$
- $A_v = A - 2\ b\ t_f + (t_w + 2r)\ t_f > \eta\ h_w\ t_w$
- Maximum deflection of the beam:

  $\delta = 5\ w\ L^4/\ 384\ EI + PL^3/48EI$

For a plaster or similar brittle finish, the deflection limits are L/250 for δ_{max} and L/350 for δ_2. Deflection checks are based on the serviceability loading.

(1) For axial compression in members the value of χ for the appropriate non-dimensional slenderness $\bar{\lambda}$ should be determined from the relevant buckling curve according to:

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \quad \text{but } \chi \le 1{,}0 \tag{6.49}$$

where $\Phi = 0{,}5\left[1 + \alpha\left(\bar{\lambda} - 0{,}2\right) + \bar{\lambda}^2\right]$

$\bar{\lambda} = \sqrt{\frac{Af_y}{N_{cr}}}$ for Class 1, 2 and 3 cross-sections

$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}}$ for Class 4 cross-sections

α is an imperfection factor

N_{cr} is the elastic critical force for the relevant buckling mode based on the gross cross sectional properties.

(2) The imperfection factor α corresponding to the appropriate buckling curve should be obtained from Table 6.1 and Table 6.2.

$$N_{cr} = \frac{\pi^2 EI}{L_{cr}^2}$$

Table 6.1: Imperfection factors for buckling curves

Buckling curve	a_0	a	b	c	d
Imperfection factor α	0,13	0,21	0,34	0,49	0,76

Table 6.2: Selection of buckling curve for a cross-section

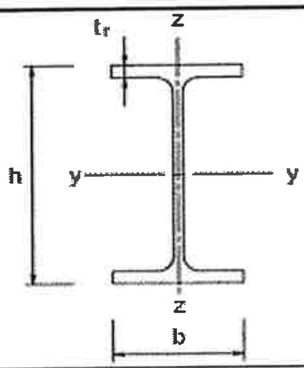
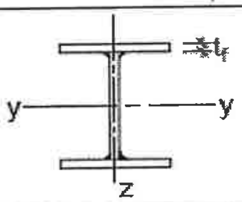
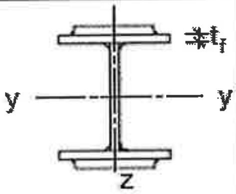
	Cross section	Limits		Buckling about axis	Buckling curve: S 235, S 275, S 355, S 420	Buckling curve: S 460
Rolled sections		$h/b > 1,2$	$t_f \leq 40$ mm	y – y z – z	a b	a_0 a_0
			40 mm $< t_f \leq 100$	y – y z – z	b c	a a
		$h/b \leq 1,2$	$t_f \leq 100$ mm	y – y z – z	b c	a a
			$t_f > 100$ mm	y – y z – z	d d	c c
Welded I-sections	 	$t_f \leq 40$ mm		y – y z – z	b c	b c
		$t_f > 40$ mm		y – y z – z	c d	c d

Table 3.3: Minimum and maximum spacing, end and edge distances

Distances and spacings, see Figure 3.1	Minimum	Maximum[1)2)3)]		
		Structures made from steels conforming to EN 10025 except steels conforming to EN 10025-5		Structures made from steels conforming to EN 10025-5
		Steel exposed to the weather or other corrosive influences	Steel not exposed to the weather or other corrosive influences	Steel used unprotected
End distance e_1	$1{,}2d_0$	$4t + 40$ mm		The larger of $8t$ or 125 mm
Edge distance e_2	$1{,}2d_0$	$4t + 40$ mm		The larger of $8t$ or 125 mm
Distance e_3 in slotted holes	$1{,}5d_0$ [4)]			
Distance e_4 in slotted holes	$1{,}5d_0$ [4)]			
Spacing p_1	$2{,}2d_0$	The smaller of $14t$ or 200 mm	The smaller of $14t$ or 200 mm	The smaller of $14t_{min}$ or 175 mm
Spacing $p_{1,0}$		The smaller of $14t$ or 200 mm		
Spacing $p_{1,i}$		The smaller of $28t$ or 400 mm		
Spacing p_2 [5)]	$2{,}4d_0$	The smaller of $14t$ or 200 mm	The smaller of $14t$ or 200 mm	The smaller of $14t_{min}$ or 175 mm

1) Maximum values for spacings, edge and end distances are unlimited, except in the following cases:
- for compression members in order to avoid local buckling and to prevent corrosion in exposed members and;
- for exposed tension members to prevent corrosion.

2) The local buckling resistance of the plate in compression between the fasteners should be calculated according to EN 1993-1-1 using $0{,}6\,p_1$ as buckling length. Local buckling between the fasteners need not to be checked if p_1/t is smaller than $9\,\varepsilon$. The edge distance should not exceed the local buckling requirements for an outstand element in the compression members, see EN 1993-1-1. The end distance is not affected by this requirement.

3) t is the thickness of the thinner outer connected part.

4) The dimensional limits for slotted holes are given in 1.2.7 Reference Standards: Group 7.

5) For staggered rows of fasteners a minimum line spacing of $p_2 = 1{,}2d_0$ may be used, provided that the minimum distance, L, between any two fasteners is greater or equal than $2{,}4d_0$, see Figure 3.1b).

Table 3.4: Design resistance for individual fasteners subjected to shear and/or tension

Failure mode	Bolts	Rivets
Shear resistance per shear plane	$F_{v,Rd} = \dfrac{\alpha_v\ f_{ub}\ A}{\gamma_{M2}}$ - where the shear plane passes through the threaded portion of the bolt (A is the tensile stress area of the bolt A_s): - for classes 4.6, 5.6 and 8.8: $\alpha_v = 0{,}6$ - for classes 4.8, 5.8, 6.8 and 10.9: $\alpha_v = 0{,}5$ - where the shear plane passes through the unthreaded portion of the bolt (A is the gross cross section of the bolt): $\alpha_v = 0{,}6$	$F_{v,Rd} = \dfrac{0{,}6\ f_{ur}\ A_0}{\gamma_{M2}}$
Bearing resistance [1), 2), 3)]	$F_{b,Rd} = \dfrac{k_1\ \alpha_b\ f_u\ d\ t}{\gamma_{M2}}$ where α_b is the smallest of α_d; $\dfrac{f_{ub}}{f_u}$ or 1,0; in the direction of load transfer: - for end bolts: $\alpha_d = \dfrac{e_1}{3d_0}$; for inner bolts: $\alpha_d = \dfrac{p_1}{3d_0} - \dfrac{1}{4}$ perpendicular to the direction of load transfer: - for edge bolts: k_1 is the smallest of $2{,}8\dfrac{e_2}{d_0} - 1{,}7$ or 2,5 - for inner bolts: k_1 is the smallest of $1{,}4\dfrac{p_2}{d_0} - 1{,}7$ or 2,5	
Tension resistance [2)]	$F_{t,Rd} = \dfrac{k_2\ f_{ub}\ A_s}{\gamma_{M2}}$ where $k_2 = 0{,}63$ for countersunk bolt, otherwise $k_2 = 0{,}9$.	$F_{t,Rd} = \dfrac{0{,}6\ f_{ur}\ A_0}{\gamma_{M2}}$
Punching shear resistance	$B_{p,Rd} = 0{,}6\,\pi\, d_m\, t_p f_u / \gamma_{M2}$	No check needed
Combined shear and tension	$\dfrac{F_{v,Ed}}{F_{v,Rd}} + \dfrac{F_{t,Ed}}{1{,}4 F_{t,Rd}} \leq 1{,}0$	

1) The bearing resistance $F_{b,Rd}$ for bolts
- in oversized holes is 0,8 times the bearing resistance for bolts in normal holes.
- in slotted holes, where the longitudinal axis of the slotted hole is perpendicular to the direction of the force transfer, is 0,6 times the bearing resistance for bolts in round, normal holes.

2) For countersunk bolt:
- the bearing resistance $F_{b,Rd}$ should be based on a plate thickness t equal to the thickness of the connected plate minus half the depth of the countersinking.
- for the determination of the tension resistance $F_{t,Rd}$ the angle and depth of countersinking should conform with 1.2.4 Reference Standards: Group 4, otherwise the tension resistance $F_{t,Rd}$ should be adjusted accordingly.

3) When the load on a bolt is not parallel to the edge, the bearing resistance may be verified separately for the bolt load components parallel and normal to the end.

3.10.2 Design for block tearing

(1) Block tearing consists of failure in shear at the row of bolts along the shear face of the hole group accompanied by tensile rupture along the line of bolt holes on the tension face of the bolt group. Figure 3.8 shows block tearing.

(2) For a symmetric bolt group subject to concentric loading the design block tearing resistance, $V_{eff,1,Rd}$ is given by:

$$V_{eff,1,Rd} = f_u A_{nt} / \gamma_{M2} + (1 / \sqrt{3}) f_y A_{nv} / \gamma_{M0} \qquad \text{... (3.9)}$$

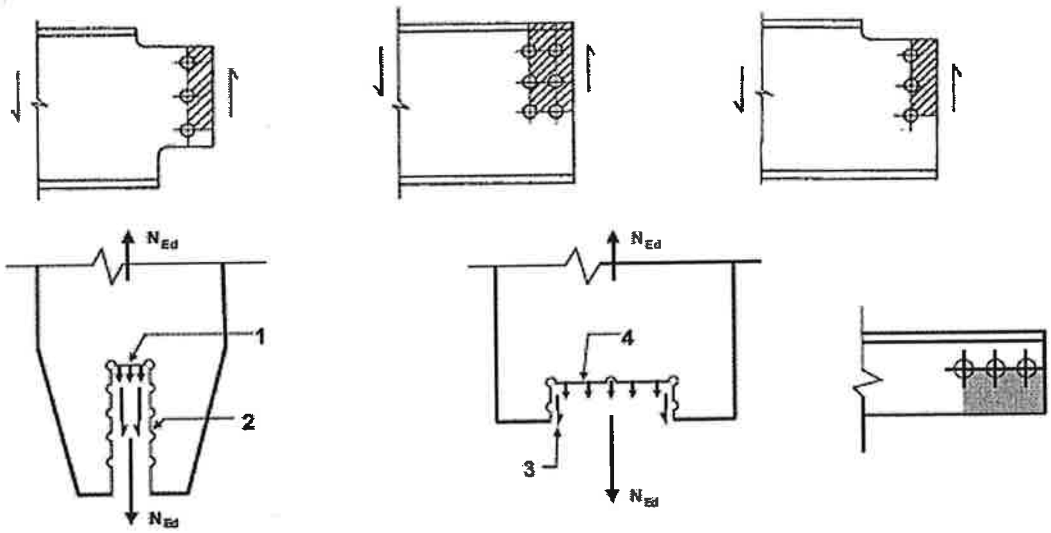
where:

A_{nt} is net area subjected to tension;

A_{nv} is net area subjected to shear.

(3) For a bolt group subject to eccentric loading the design block shear tearing resistance $V_{eff,2,Rd}$ is given by:

$$V_{eff,2,Rd} = 0{,}5\, f_u A_{nt} / \gamma_{M2} + (1 / \sqrt{3}) f_y A_{nv} / \gamma_{M0} \qquad \text{... (3.10)}$$



1 small tension force
2 large shear force
3 small shear force
4 large tension force

Figure 3.8: Block tearing